

## Drill string and components

This chapter of the IADC Drilling Manual is concerned with the specifications, operating data, and the care and handling of drill string. It will also discuss troubleshooting of the problems that may occur.

The IADC definition of a drill string is drillpipe with tool joints attached. Drill stem is all those members between the swivel and the bit, and it includes drill string, kelly or top drive, subs, drill collars, heavy weight drillpipe, stabilizers, shock absorbers, reamers and any other in-hole equipment used generally or part-time during drilling operations.

### API/ISO specifications

In the worldwide oil industry today, an overwhelming majority of all tubular goods are manufactured to specifications developed and approved by the American Petroleum Institute. These specifications cover the mechanical properties of the steel, the details of manufacture and physical dimensions of the pipe. The latter include internal and external diameters, wall thickness, and upset dimensions for each nominal size, weight and grade, as well as tool joint type, OD and ID, and length. API Specification 5DP covers drillpipe. Bulletins 5A2, 5C2, and 5C3 cover aspects of the use of and care of drillpipe wall thickness or that joints would mate with similar products manufactured by different companies.

To mitigate the resulting confusion and loss of time, the API was induced to undertake a program of standardization and marking. This program is a continuing one which enables changes to occur based upon improved technology and the needs of users and manufacturers to be disseminated to the industry in a minimum amount of time and with a high degree of accuracy. API Specifications and Recommended Practices cover a wide range of oilfield equipment in addition to tubular goods. These publications are revised as necessary and constitute one of the best sources of information on the design, manufacture, care, and use of drilling and production equipment.

This section of the Drilling Manual relates not only to the API 5DP specifications, but also to Recommended Practice RP7G and RP7A1. These publications relate to the connections for the drill string and also to the design and operating limits of the drill stem.

This section of the Drilling Manual discusses drill string care and use and gives examples of the types of problems usually encountered when the drill string is improperly used or used beyond its physical capabilities. This section also recommends practices which will overcome or eliminate the problems often encountered when using the drill stem.

In the oil industry today, most drillpipe is manufactured to specifications developed and approved by API/ISO. This

**Table DS-1: Drill pipe grades.**

Current Grades	Grade Code	Minimum Yield (psi)
E-75	E	75,000
X-95	X	95,000
G-105	G	105,000
S-135	S	135,000
Z-140*	Z	140,000
V-150*	V	150,000
U-165*	U	165,000

Drill pipe tubes are furnished in the following API length ranges:

- Range 1: 18-22 ft;
- Range 2: 27-30 ft;
- Range 3: 38-45 ft.

includes mechanical properties of the steel and physical dimensions of the tubes and their upsets.

Normal tolerance on yield strength of drillpipe tubes is plus 30,000 psi. All grades above E-75 are referred to as high strength. Grades marked with an asterisk have been used, but not been formally recognized.

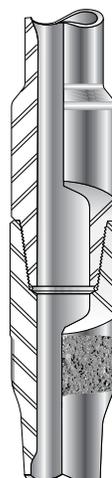
The production of high-strength drill-pipe tube began in the 1950s. When high strength tubes were accepted by API some 10 years later, tool joint dimensions (ODs and IDs) were those commonly used on E75 tubes. A committee was appointed, and tool-joint dimensions recommended, with the result that the torsional yield of the tool-joint pin was at least 80% as strong as the tube to which it was to be attached.

Good practice is for the tool-joint box to be stronger than the pin initially, because wear will ultimately make the box the weaker member.

The attaching of tool joints to upset drillpipe tubes by flash welding was replaced in the 1970s by inertia and friction welding. API/ISO specifications require the weld to be stronger than the tube body, have good ductility, and not be harder than 37 Rockwell C.

Most sizes of drill-pipe tubes come in light weight, standard weight, and one or more heavier than standard weights. Both the grade code and the weight code should be stenciled on the pin base for finished drill string assemblies. It is recommended that these two codes (grade and weight) also be stenciled on a milled flat on the pin tong surface for quick identification. The numeric code is 1 for a light-weight tube and 2 for a standard weight tube. Heavier-than-standard tubes receive a 3, 4, or 5. Most of the tubes today are standard weight, and these receive the 2 designation. A complete

Table DS-2: Tool joint connections.	
Grade code	Description
IF	Internal Flush
EH or XH	Extra Hole
SH	Slim Hole
OH	Open Hole
SL - H-90	Slim Line-Hughes-90
FH	Full Hole
H-90	Hughes-90
WO	Wide Open
NC	Numbered Connection



**Figure DS-1:** Weld-on tool joint. The flash-welded tool joint, introduced in 1938, was the industry's first weld-on tool. Inertia welding was introduced in 1974 and continuous-drive friction welding in 1978.

list of these may be found in API 5DP in **Table C-12**. Drill string nomenclature and abbreviations are detailed in **Table DS-2**.

## Drillpipe description and basic theory

### General information

The drill string is required to serve three basic functions:

- Transmit and support axial loads;
- Transmit and support torsional loads;
- Transmit hydraulics.

The design parameters and a step-by-step procedure of designing a string are given in API RP 7G, 16th ed, Section 7.

Another recommended source document is G. K. McKown, *Drill String Optimization for High-Angle Wells*, 1989 SPE/IADC Drilling Conference, SPE/IADC 18650.

Seamless drillpipe is offered in the grades listed below under "Mechanical Properties API Steel Drill Pipe". The drill string is used to transmit power by rotary motion from surface to a drill bit at the bottom of the hole, to convey flushing media to the cutting face of the tool, and to carry cuttings out of the hole. Thus, it plays a vital part in the successful drilling of oil and gas wells.

Here are commonly used abbreviations for drill-pipe upsets:

- IU: Internal upset;
- EU: External upset;
- IEU: Internal-external upset.

Table DS-3: Interchangeability chart for tool joints.						
NC	NC26	NC31	NC38	NC40	NC46	NC50
Internal flush	2 7/8	2 7/8	3 1/2		4	4 1/2
Full hole				4		
Extra hole		3 1/2			4 1/2	5
Wide open			3 1/2		4	5
Slim hole	2 7/8	4	4 1/2			

With the exception of specialty tools, probably no other part of the drill stem is subjected to the complex stresses which drill string must withstand. For this reason, the combined skills of steel-industry engineers, with full cooperation from oil companies and drilling contractors and in conjunction with API and IADC, have been used in the development of this vital tool. The same skill was utilized in formulating suggested practices in the care and handling of pipe on the surface, while making trips in and out of the hole and while drilling. With this information, contractors and operators can extend drill-string life and realize improve project economics.

Drill string is an important and expensive part of the rig, but suffers from a relatively short life. The cost of the drill string places it in the category of a capital investment. It is not strictly expendable. A recommended practice, followed by many contractors, is to identify each joint upon purchase with an alpha-numeric serial. This serial number, along with the length of the joint, should be recorded when it is placed

Table DS-4: Mechanical properties of API steel drill pipe.				
Grade	E-75	X-95	G-105	S-135
Yield Strength (minimum psi)	75,000	95,000	105,000	135,000
Yield Strength (maximum psi)	105,000	125,000	135,000	165,000
Tensile Strength (minimum psi)	100,000	105,000	115,000	145,000

in the string. This practice, along with field support and office accounting, will facilitate:

- Determining the useful life of the joint;
- Recording types of service and stresses the joint might be exposed to;
- Switching within the string to optimize use;
- Determining causes of failures more accurately;
- Preventing or minimizing downhole failures.

### Grades and lengths of steel drillpipe

As discussed in API/ISO Specifications above, drillpipe tubes are furnished in the following API length ranges:

- Range 1: 18-22 ft;
- Range 2: 27-30 ft;
- Range 3: 38-45 ft.

### Marking

Drillpipe identification is marked at the base of the pin by the tool joint manufacturer after the pin is affixed. The marking will be in accordance with **Figure DS-2**. It is further recommended that drillpipe other than standard weight Grade E-75, be marked according to **Figures DS-3 through DS-5**. This is to give the crew rapid identification of high strength drillpipe on the racks and on the floor during trips when it is in a combination string with **Grade E-75**. With little trouble, if necessary cleaning out the milled slot, the specific grade and weight can be determined from the stenciled figures. joint OD surfaces should be performed, with an emphasis on detection of longitudinal cracks.

- In highly stressed drilling environments or if evidence of fatigue damage is noted, magnetic particle inspection should be made of the entire box threaded area, especially the last engaged thread area, to determine if transverse cracks are present.
- The wet fluorescent magnetic particle method is preferred.

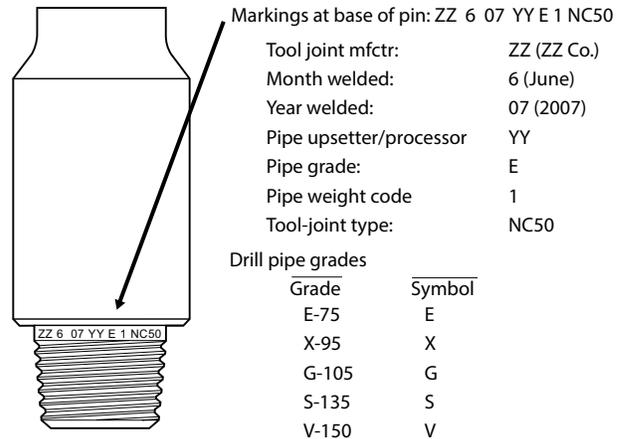
### Weld-on tool joint description/basic theory

The flash welded tool joint was the first weld-on type tool joint introduced to the industry in 1938. Inertia welding was offered in 1974 and continuous-drive friction welding in 1978. **Figure DS-1** illustrates weld-on tool joint.

Both inertia and continuous-drive friction welders use frictional heat for achieving welding temperatures. However, the inertia welder uses a flywheel and momentum principle, whereas the continuous drive-friction welder maintains a constant rpm motor and brake system.

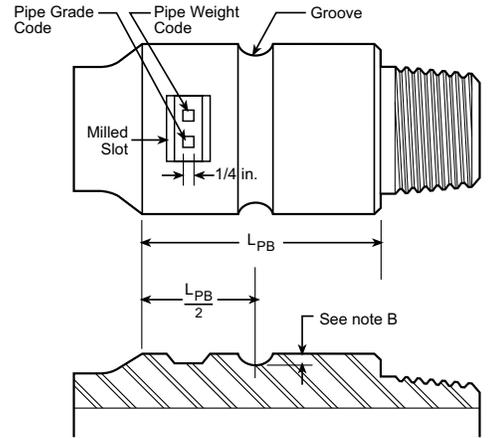
### Tool-joint selection

For many years tool joints have had a minimum yield strength of 120,000 psi. The old IF, XH, FH, etc., have been replaced with Numbered Connection series - NC plus a number in-

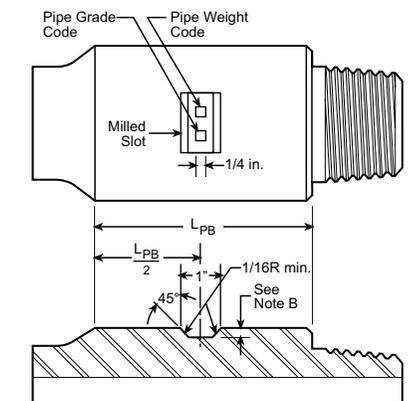


**Figure DS-2:** Tool joint markings for component identification.

Note: Pin base marks should be clear and legible and not struck over with manufacturing data.



**Figure DS-3:** Identification of standard weight high strength drill pipe. (Refer to notes on p DS-4.)



**Figure DS-4:** Identification of heavier-than-standard weight Grade E-75 drill pipe. (Refer to notes on p DS-4.)

dicating pitch diameter in inches and tenths. NC46 replaces the old 4 1/2-in. Extra Hole (XH). The NC series have the same "V" threads, but with a 0.038-in. rounded root radius. This offers a slightly better fatigue life and a slightly smaller cross section.

**Table DS-3** shows the interchangeability between NC connections and the old style designations.

### ***Torsional strength***

The torsional strength of a tool joint is a function of several variables. These include the strength of the steel, connection size, thread form, lead, taper, and coefficient of friction on the mating surfaces of threads and shoulders. The torque required to yield a rotary-shouldered connection may be obtained from the equation in Appendix A, API RP7G.

The pin or box area, whichever controls, is the largest factor and is subject to the widest variation. The tool-joint outside diameter (OD) and inside diameter (ID) largely determine the strength of the joint in torsion. The OD affects the box area and the ID affects the pin area. Choice of OD and ID determines the areas of the pin and box and establishes the theoretical torsional strength, assuming all other factors are constant.

OD wear causes the greatest reduction in theoretical torsional strength of a tool joint. At whatever point the tool-joint box area becomes the smaller or controlling area, any further reduction in OD causes a direct reduction in torsional strength. If the box area controls when the tool joint is new, initial OD wear reduces torsional strength. It is possible to increase torsional strength by making joints with oversized OD and reduced ID.

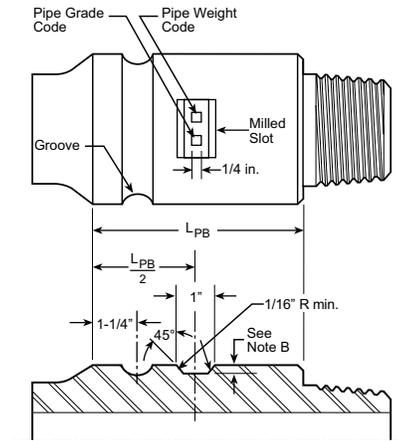
### ***Elevator shoulder design***

Tool joint box elevator shoulders are manufactured in both the square and 18° taper. Most weld-on type tool joints are furnished with tapered shoulders.

Tool joint pins are generally furnished with 35° tapered shoulders, but can be made available with an 18° tapered shoulder.

Elevators are available to work with either 18° tapered or square-shouldered joints. Those for use with the 18° tapered shoulders are generally heavier due to the higher radial loading that results from the wedging action. API Specification 8C specifies elevator bores to correspond to dimensions of the box elevator upset.

On some tool joint assemblies, such as slim hole, lifting plugs are used to provide the elevator shoulder necessary to handle the drill string.



**Figure DS-5:** Identification of heavier-than-standard weight high-strength drill pipe. (Refer to notes below.)

**Note A:** Standard weight Grade E-75 drill pipe designated by an asterisk (\*) in the drill pipe weight code will have no groove or milled slot for identification. Grade E-75 heavier than standard weight drill pipe will have a milled slot only in the center of the tong space.

**Note B:** Groove radius approximately 3/8-in. Groove and milled slot to be 1/4-in. deep on 5 1/4-in. OD and larger tool joints, 3/16 in. deep on 5-in. OD and smaller tool joints.

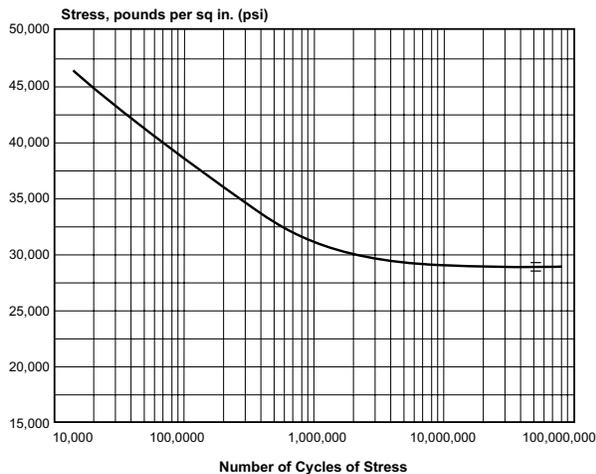
**Note C:** Stencil the grade code symbol and weight code number corresponding to grade and weight of pipe in milled slot of pin. Stencil with 1/4-in. high characters so marking may be read with drill pipe hanging in elevators.



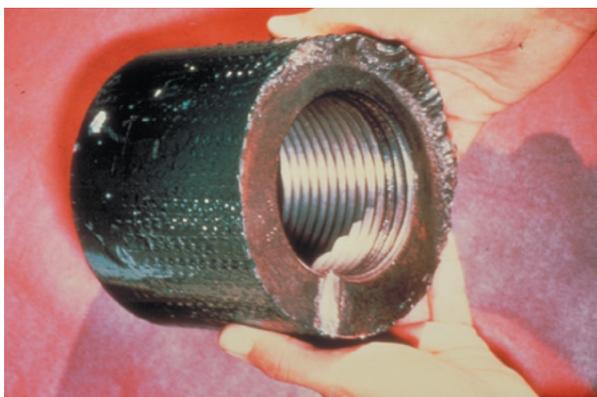
**Figure DS-6:** Plastic coating in the pin bore acts as a stress coat and serves as an early indicator of pin stretch.



**Figure DS-7:** Thread protectors will prevent most tool-joint damage that can occur during moving or racking.



**Figure DS-8:** S-N curve of mild steel shows number of cycles under stress to produce failure.



**Figure DS-9:** Example of pure fatigue in a drill string box.

### ***Tool-joint markings***

It is recommended that weld on tool joints be stenciled on the base of the pin with the information shown in **Figure DS-2**. In addition, it is further recommended that drillpipe weight and grade identification as shown in **Figure DS-3, -4 and -5** be used.

### ***Drillpipe upsets for weld-on tool joints***

Drillpipe must have upsets for installation of weld-on type tool joints. This allows an adequate safety factor in the weld area for mechanical strength and metallurgical considerations. The tool joint is made with a welding neck or tang to facilitate welding API upsets for various sizes, grades and weights of drillpipe listed in API 5DP.

### ***High-strength drillpipe***

Because of deeper drilling and higher stress levels, grades of drillpipe stronger than Grade E-75 have been developed. High-strength drillpipe requires heavier and longer upsets than those used on Grade E-75. Tool joints on high-strength drillpipe are designed to fit the same elevators as those used for the Grade E-75 assemblies.

### ***Cleaning and inspection***

Pin and box thread and shoulders should be thoroughly cleaned to prepare them for adding to the string. Cleaning pays off in three ways. Cleaning:

- Removes foreign material and permits proper make-up, thereby reducing danger of galling and wobbles;
- Permits better inspection;
- Increases the life of connections by eliminating abrasive materials.

Connections should be thoroughly dried after cleaning so that the thread compound will properly adhere to the surface. An approved way to clean tool joint threads and shoulders is to wet the connection with kerosene or diesel; then brush with ordinary gel. Catch the old dope and gel and dispose of properly. This will leave connections clean and dry for visual inspection and for applying fresh thread compound.

After cleaning, inspect thread and shoulders carefully. Damaged connections should never be run in the hole. Even slight damage will likely cause wobbling or leaking. Slight damage may be repaired at the rig with a shoulder dressing tool or file. Test each box and pin shoulder with a shoulder dressing tool test ring. Use the benchmark to make sure that no tool joint shoulder has been dressed beyond recommended limits. Check the plastic coating in the pin bore under the last engaged thread as a first check on pin stretch (**Figure DS-6**). After inspection, protect all boxes and pins with clean, dry thread protectors.